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"The Mid-ocean Ridge Basalt Ferric Iron Crisis"

Abstract:
Mid-ocean ridge basalts are among the most direct samples we have for inferring the chemical and thermal state of the Earth's upper mantle. Their major and trace element compositions can be readily analyzed because the rims of erupted flows quench to homogeneous glass. However, most of the routine analytical methods used do not distinguish the oxidation state of the observed elements, so the relatively few measurements of oxidation state, especially of iron, are disproportionately influential. In fact, the analytical estimates for the ferric iron (Fe3+ or Fe(III)) to total iron ratio of mid-ocean ridge basalt glasses have been creeping up over time, from 0.08 in 1986 to 0.16 today. The implications for the oxidation state of the mantle and the history of recycling of oxidized material by subduction are obvious, but there is a different set of implications that have not been worked out. Our models that use the composition and thickness of oceanic crust to constrain the temperature and melting behavior of the oceanic mantle are very strongly dependent on Fe/Mg partitioning between melt and olivine, in which only ferrous iron (Fe2+ or Fe(II)) counts. Previously these models seemed to work and offer a consistent solution wherein the mantle temperature that yields the right composition of primary basalt also yields the right thickness of oceanic crust, and fractionation of that primary basalt yields a complementary relationship between the cumulate lower crust and the volcanic upper crust. But increasing the ferric iron fraction breaks that consistency. It lowers the inferred temperature and MgO content of the estimated primary magma, leaving very little room to form cumulates by fractionation and also requiring colder mantle that, in turn, does not provide enough predicted melt to explain the thickness of oceanic crust. I will explore these issues quantitatively using the PRIMELT3 and MELTS models and we will seek for a new coherent understanding, which will require changing either our analytical, numerical, or conceptual framework for interpreting the oceanic crust.